AFOSR 70-0929TR

Development of a Taxonomy of Human Performance:

A Review of Biological Taxonomy and Classification

AD705255

George C. Theologus

Technical Report 3

DECEMBER 1969

1. This document has been approved for public release and sale; its distribution is unlimited.

AMERICAN INSTITUTES FOR RESEARCH
WASHINGTON OFFICE
Address: 8555 Sixteenth Street, Silver Spring, Maryland 20910
Telephone: (301) 587-8201

R70-4

AMERICAN INSTITUTES FOR RESEARCH

WASHINGTON OFFICE

EDWIN A. FLEISHMAN, PhD, DIRECTOR
Arthur L. Korotkin, PhD, Assistant Director

INSTITUTE FOR COMMUNICATION RESEARCH

George H. Johnson, PhD, Director

Research on instructional, communication, and information systems and their effectiveness in meeting individual and social needs.

COMMUNICATION SKILLS RESEARCH PROGRAM
Herbert L. Friedman, PhD, Director

EDUCATIONAL RESEARCH AND EVALUATION PROGRAM
George H. Johnson, PhD, Director

INFORMATION AND COMPUTER SCIENCES PROGRAM
Arthur L. Korotkin, PhD, Director

INSTITUTE FOR RESEARCH ON ORGANIZATIONAL BEHAVIOR

Albert S. Glickman, PhD, Director

Research on individual, interpersonal, and group behavior as they relate to organizational functioning and effectiveness of social systems.

HUMAN RESOURCES RESEARCH PROGRAM
Clifford P. Hahn, MS, Director

MANAGEMENT RESEARCH PROGRAM
Albert S. Glickman, PhD, Director

URBAN DEVELOPMENT RESEARCH PROGRAM
Robert H. Fosen, PhD, Director

INSTITUTE FOR RESEARCH IN PSYCHOBIOLOGY

Warren H. Teichner, PhD, Director

Human and animal psychophysiological and behavioral research related to the areas of performance theory, stress, and technological systems.

ANIMAL RESEARCH LABORATORY
BIOTECHNOLOGY RESEARCH LABORATORY
HUMAN PERFORMANCE RESEARCH LABORATORY

INTERNATIONAL RESEARCH INSTITUTE

Paul Spector, PhD, Director
Henry P. David, PhD, Associate Director
Stanley Lichtenstein, PhD, Director of Studies

Research on the development of human resources in developing countries; problems of working effectively abroad; evaluation of action programs in the underdeveloped countries; role of attitudes and values in social change and economic development; and research on family planning and population.

INTER-CULTURAL RESEARCH PROGRAM
Robert L. Humphrey, MA, LLB, Director

AFOSR 70-0929TR

AIR-726-12/69-TR-3

DEVELOPMENT OF A TAXONOMY OF HUMAN PERFORMANCE:

A Review of Biological Taxonomy and Classification

George C. Theologus

TECHNICAL REPORT NUMBER 3

Prepared under Contract for
Advanced Research Projects Agency
Department of Defense
ARPA Order No. 1032

Principal Investigator: Edwin A. Fleishman
Contract No. F44620-67-C-0116

American Institutes for Research
Washington Office
Institute for Research in Psychobiology

December 1969

ABSTRACT

This review of systematic biology was undertaken to determine whether any of the concepts and methods from systematic biology could be applied to the problems of task taxonomy and task classification. Although the review found that biology could not supply ready solutions to problems in the classification of tasks, certain taxonomic concepts were extracted which should be of value. The importance of a well-developed logic and rationale for classification was noted. Moreover, it was determined that the purpose of a classification must be established before the nature of the objects to be classified or the methods of classification can be specified. In considering the logic for classification three types of classification were identified and defined: teleological, consociative, and theoretical classification. Of these three, only theoretical classifications, classifications which describe the objects of interest in terms of inherent attributes of the objects themselves, are generally applicable or theoretically useful. Three approaches to the development of theoretical classification also were considered. Linnaean taxonomy which employs scholastic logic to develop classifications and Darwinian taxonomy which employs a deductive theory were rejected for use in task classification on the basis of their vulnerability to criticism. Numerical taxonomy, the most empirical of the three biological approaches to classification, was found to provide a sound basis for the development of classificatory systems and was suggested as a model for the development of task classifications.

PREFACE

The present review of biological taxonomy and classification was undertaken as part of a larger effort concerning the development of a classification system for tasks currently being conducted by the American Institutes for Research. The purpose of the review was to determine whether any of biology's taxonomic concepts and methods could be applied to the problems of task classification. It was undertaken as an overview of the field in the hope of identifying those aspects of biological taxonomy which might be most helpful to the development of a task taxonomy. In this sense, this report should be viewed as neither a critique nor an analysis, nor even an exhaustive review of the technical complexities of the biological problem, but rather as an introduction to the field, biased toward the question of applicability to classifying human performance.

The discussion of biological taxonomy and classification which is to follow will be divided into three sections formed by asking: (1) why do biologists classify, (2) what do they classify, and (3) how do they classify. At each of these three points an attempt will be made to relate the biologists' efforts to the problems of task taxonomy and task classification. However, before beginning the discussion, five definitions will be provided along with a short introduction to the body of the discussion. The definitions hopefully will provide the basis for a consistent terminology and the introduction will comment upon the value of the biologists' efforts with respect to the problems of task taxonomy and task classification.

Definitions

Although no definitions of key taxonomic terms would be accepted by all biologists, the first four definitions, given below, probably would be accepted by most. The fifth definition is an outgrowth of a rather new development in biology, Numerical taxonomy[1], and as such, has been accepted and utilized primarily by the Numerical taxonomists.

1. Systematics "is the scientific study of the kinds and diversity of organisms and of any and all relations among them" (Sokal & Sneath, 1963, p. 3).

2. Taxonomy "is the theoretical study of classification, including its bases, principles, procedures, and rules" (Sokal & Sneath, 1963, p. 3).

3. Classification "is the ordering of organisms into groups (or sets) on the basis of their relationships, that is, of their associations by contiguity, similarity, or both" (Sokal & Sneath, 1963, p. 3).[2]

4. Zoological nomenclature "is the application of distinctive names to each of the groups recognized in any given zoological classification" (Simpson, 1961, p. 9).

5. A unit character "is a taxonomic unit of two or more states, which within the study at hand, cannot be subdivided logically except for subdivision brought about by changes in the method of coding" (Sokal & Sneath, 1963, p. 65).

---

[1] Numerical taxonomy is "the numerical evaluation of the affinity or similarity between taxonomic units and the ordering of these units into taxa on the basis of their affinities" (Sokal & Sneath, 1963, p. 48).

[2] These first three definitions, with minor variations, can also be found in Simpson (1961) on pages 7, 9, and 11, respectively.

One can readily see that the above definitions are either applicable to task taxonomy as they stand, or can be made applicable by the substitution of a word. The definitions of taxonomy and unit character need no modification. The definitions of systematics and classification can be made specific to our purpose by the substitution of the word "tasks" for the word "organisms" and, in the definition of zoological nomenclature, "psychological" should be substituted for "zoological".

As they are defined above, the definitions of systematics, taxonomy, and classification assume a hierarchical order. The subject matter of classification is organisms; the subject matter of taxonomy is classifications; and systematics is the science which encompasses both of them. In the systematics of tasks, the words taxonomy and classification have been used interchangeably with a resulting loss of clarity in communication. To insure adequate communication among systematic psychologists, the hierarchical ordering of these terms should be recognized and the distinctions among them should be preserved. Thus, in this report, a taxonomy is a set of theoretical principles, procedures, and rules, which serve as a philosophical and logical basis for classification, and a task classification is a set of classes into which tasks can be placed on the basis of their associations by contiguity, similarity, or both.

With regard to the clarity of the five definitions, only the definition of taxonomy stands on its own without need of any further elucidation. Each of the other definitions deserves a few words.

Systematics and classification. The relations among organisms which are referred to in the definition of systematics are the associations by contiguity and similarity specified in the definition of classification. Simpson states what the biologists mean by associations by contiguity and similarity. "Association by contiguity .... is a structural and functional relationship among things that, in a different psychological terminology, enter into a single Gestalt. The things involved may be quite dissimilar, or in any event their similarity is irrelevant" (Simpson, 1961, p. 3).[3] A biological example of functional association by contiguity is the relationship between a plant and the soil in which it grows. An example of structurally contiguous association is the leaf on the tree. This concept of association by contiguity can be extended to fit our purposes, since it is basically a statement of conditional probability, a statement of co-occurrence. Thus, for our purposes we can say that contiguous association exists between any two objects or events, A and B, whenever $P(A/B) > 0$. Simpson (1961) also defines association by similarity. It is "simply the classing together of various different things because all possess some one or more common characteristics" (p. 3). In this case, the structural and functional relationships among the things are irrelevant. Furthermore, it makes no difference if the objects interact. The concept of association by similarity is applicable to task classification without any modification.

[3] It should be noted that Simpson also states that association by contiguity can be established on the basis of evolutionary origin and phylogenetic relationships.

Nomenclature. When examining the definition of nomenclature it is important to note that nomenclature is an essential adjunct or secondary outcome of classification and, hence, does not in itself constitute classification. Nomenclature is an exercise carried out only when a group has been previously recognized. There is a logical priority of classification over the development of collective names or symbols.

Unit character. In the definition of unit character, there are several points which could stand some comment. First, as it is defined above, a unit character is the basic unit of information to be studied, and it is the basic unit upon which organisms are to be compared. The usage of the term by Sokal and Sneath relates it closely to information theory. In fact, Sneath (1957a) attempted to introduce the concept of information into the definition. In that article the word "feature" was used instead of "unit character" and it was defined as an attribute possessed by an organism about which one statement can be made, thus, yielding a single piece of information.

Second, it should be noted that a unit character (or a feature as defined above) is a formally logical construct, since it will change if the technique of observation changes. Thus, the definition of a unit character in any given study is strictly operational.

Third, the nature of the unit characters chosen for any given classification is dependent upon the purpose of the classification. For example, in classifying tasks as tasks the unit characters must be specific attributes of the tasks themselves and must not relate to anything else such as training or systems design.

Fourth, the meaning of the phrase, "two or more states" in the definition of unit character should be further clarified. Sokal and Sneath allow for the possibility that the two states may be the

presence or absence of the unit; e. g., the presence of absence of a bristle on an organism. However, some considerations should be noted when the absence of a unit, or an assigned zero, is used in assessing simularity among objects.[4] Sneath (1957a) summarizes these considerations in the following fashion.

> "If two organisms both possess the same positive feature this counts as one similarity; if one possesses it and the other does not this counts as one difference; if neither possesses it this does not count at all. This is logical, since it is not pertinent to count 'lack of feathers' as a feature when comparing bacteria with one another, but it would be pertinent in comparing a bacterium with a bird. If one admits to comparisons between negative features one does not know where to stop" (p. 205).

One other point concerning assigned zeros should be made. If their use is looked upon as definition by negation, then, the list of attributes must be exhaustive.

The final part of the definition of unit character which needs explanation is the phrase, "cannot be subdivided logically, except for subdivisions brought about by changes in the method of coding". This phrase simply means that the method of coding or the unit of measurement is not relevant to the definition. To stay with the example of length of bristles, length is length whether it is in feet, inches, or angstroms. The change in scale merely influences the fineness of the determination of the length of the bristles.

---

[4] Although this point is raised here since it is germane to the definition of unit character, a detailed discussion of it will not be undertaken.

TABLE OF CONTENTS

INTRODUCTION

It can be safely stated that psychologists have no real interest in whether Dasyosmia and Crytosmia are distinct taxa or whether they should be grouped as one. The content of biological classifications is irrelevant to our purpose. What are of importance are the principles, procedures, and rules which the biologists employ in classifying. In other words, we are interested in their taxonomy and not in their classification. In examining their taxonomy it can be quickly recognized that it is quite incomplete and that, for all their classification, their taxonomy is rather ill-developed. This is largely due to the fact that the vast majority of biologists have addressed themselves to classification rather than to taxonomy.[5] Among the biologists, there has been a distinct tendency to be too ready to classify. The fundamental logic, which is essential to classification, has been generally ignored. In 1940, Gilmour stated that "Biologists have fought shy of what is often called mere word-splitting or worse, and have left the philosophical foundations of their science to look after themselves, or rather to be pulled down and rebuilt by the philosophers" (p. 463). This disregard and distain for taxonomy has resulted in a multitude of ill-conceived, poorly developed classification systems, few of which appear to offer any real service for the science of biology.

Just like the biologists, psychologists working in the area of psychological systematics have displayed a great interest in

---

[5] There has been a recent resurgence of interest in taxonomy among biologists. This movement had its roots in the 1930's, but has yet to produce a definitive work. Two major schools of thought have emerged: Darwinian or evolutionary taxonomy (Simpson, 1961) and Adansonian or empirical taxonomy (Sokal & Sneath, 1963).

classification but very little interest in taxonomy. In reviewing the paper by Wheaton (1968) on task taxonomy and task classifications, one of the most striking points is the failure of the vast majority of classifiers to adequately consider taxonomic problems. The inevitable result of this failure is the generally unsatisfactory nature of the various task classifications which have been developed. If the basic logic is ignored and, as a result, logical errors exist in the foundation and formulation of an approach to classification, then the effort is almost certainly destined for failure.

Thus, in task taxonomy a logic for classification should be developed very carefully before classification is attempted, no matter what approach is finally chosen. Failure to take this necessary step will only serve to minimize any chances for success.

WHY DO BIOLOGISTS CLASSIFY?

It seems as though there are almost as many reasons for classification in biology as there are biologists. Quite often it would appear that each biologist has some different purpose in mind for his classification although in many instances the differences in purpose may be quite small. Even though this situation exists, some general statements about the "why" of biological classification can be made and some general "categories" for the biological classifications can be formed.

At the most basic level biologists classify in an attempt to supply some order[6] and organization to the vast number of living organisms which they observe. This point is made explicit by Gilmour (1937): "Fundamentally, the purpose of biological classification is the acquisition of ordered knowledge regarding living things" (p. 1040). This order is necessary for the biologists since, if each organism were to be considered as distinct and unique, as an object unrelated to any other thing, an observer would be hard pressed to extract any meaning from the onslaught of unconnected perceptions. In order to obtain meaning from what would otherwise be a totally meaningless and confusing set of perceptions, the observer must attempt to simplify his perceptions. The basic aim of science is to carry this simplification or this reduction of chaos to the highest possible level. Scientists do and must tolerate

---

[6] The question as to whether this order is imposed upon nature by the observer or whether it is inherent in nature is intentionally ignored at this point since a treatment of it would not appear to aid in the overall discussion of biological taxonomy and classification.

uncertainty, but they do not and must not tolerate disorder. In an effort to eliminate disorder the scientist employs the scientific method in which the basic step for simplification, and hence, for understanding is classification.[7]

Given that order is the primal purpose of all scientific classification both within and without biology, other purposes for biological classifications can be specified. Classification can be undertaken because one wants to relate organisms to some exoteric variable or set of variables of interest, because one wants to show the usefulness of some organism to man, or because one wants to reveal the interrelationships among organisms themselves. Specification of these purposes leads to the definition of three general types of biological classification: ecological, teleological, and theoretical.[8] All biological classifications can be subsumed under one of these types of classification. As will be shown below, each of these types of classification has an analogous counterpart in task taxonomy and classification.

Ecological Classification

"Ecological classification defines sets (or organisms)[9] according to such criteria as the communities in which the organisms live...or other environmental factors..." (Simpson, 1961, p. 26). Examples of ecological classifications are fresh-water fishes,

---

[7] A brief outline of the scientific method is given in the Appendix.

[8] The terms, ecological classification and teleological classification were obtained from Simpson (1961). The term, theoretical classification, was developed by the present author to supply a label for an apparent group of classifications.

[9] The phrase in the parentheses was added by the present author.

tropical plants, forest insects, and cave salamanders. The number of such classifications which could possibly be constructed is limited only by the number of environmental factors which could be found to serve as bases for classification. The choice of an environmental factor to serve as a basis for classification is dependent upon the eventual use of the classification. A state wildlife manager attempting to stock trout in a state's streams might employ food supply, water temperature, and depth of the water as the bases for his classification. As can be seen in this example, the usefulness of ecological classifications is for particular and specific purposes. In fact, no biologist would ever propose a general usefulness for ecological classifications nor would he suggest that a theory of organisms could be developed around such a classification. The reason for this is that ecological classifications describe the organisms in terms of environmental factors (e.g., fresh-water fishes) and hence, supply little or no information about the organisms themselves. In other words, in ecological classification the nature of the application of the classification determines the structure of the classification. The analogue of ecological classification in task classification will be referred to as consociative[10] classification. Consociative classification of tasks would be the classification of tasks with respect to variables of interest which are not inherent attributes or characteristics of the tasks themselves, such as the operator's basic abilities, behavior requirements, or inferred processes in the operator. As can be seen in Wheaton's review (1968) the overwhelming majority of task classifications are of this type.

---

[10] The word "consociative" is substituted for the word "ecological" because of the inherent biological meaning in the word "ecological".

Teleological Classification

"Teleological classifications define sets (of organisms)[11] according to their usefulness or lack of it, usually with respect to man. Such sets might be, for example: domesticated animals, with meat animals, draft animals, pets, etc. as subsets; edible, non-edible, and poisonous fishes..." (Simpson, 1961, p. 26). The concept of usefulness, as it is employed in this definition, merely refers to the fact that the usefulness of the organisms to man serves as a basis for classification; it in no way refers to the over-all pragmatic value of the classification. Any and all classifications can be useful regardless of the basis for classification. In general, teleological classifications are of little scientific interest to biologists and they usually require prior classification of the organisms on some other system. However, in some instances they do serve a definite and valuable function. For example, a teleological classification could serve research on natural herbal remedies. The most obvious teleological classification in task classification is R. B. Miller's classification of tasks into "nonsense tasks" and "real world tasks".

Theoretical Classification

Theoretical classifications define sets of organisms with respect to the attributes or characteristics of the organisms themselves. As contrasted with ecological classification, the structure of theoretical classifications is not determined by the application of the classification. Theoretical classification is the most widely employed type of classification in biology and it is the only one for

[11] The phrase in the parentheses was added by the present author.

which biologists posit a general usefulness. The general usefulness of theoretical classifications is derived from the fact that they are the only biological classifications which describe the relationships among organisms in terms of the attributes of the organisms themselves and as a result they are the only classificatory vehicle which can relate this essential information to other things such as the environment (ecological) or usefulness (teleological). In addition to their general usefulness, they are the only type of classification out of which the biologists would attempt to extrapolate a theory of organisms. The only example of a theoretical classification in task classification is Hackman's task <u>qua</u> task approach (1968) and even this is not developed into a working classificatory system.

An interesting point to note here is the difference in theory-building-value which the biologists and psychologists attribute to the various types of classification. Regardless of the debates among biologists concerning other taxonomic issues, all biologists agree that theoretical classification is the only type of classification which has a general usefulness and a theoretical value, since it is the only type of classification in which the relationships among organisms, and among organisms and exoteric variables are described in terms of the characteristics of the organisms themselves. Psychologists, on the other hand, have made little effort in developing a theoretical classification of tasks, and instead, have suggested that consociative classifications of tasks have a general usefulness and that a theory of tasks should be sought in a consociative classification of tasks. These suggestions appear to gloss over a basic difference between consociative and theoretical classifications. This difference is quite important in that it has an impact upon what can be obtained from a classification. If, for

example, the causes of certain behaviors on certain tasks are important to the systematist, then a consociative classification is inadequate. One cannot get at the nature of the causes (tasks) when the description of the causes is in terms of the effects (behaviors). It would appear illogical to attempt to describe the impact of tasks on, let us say, performance when the tasks are described in terms of performance requirements. In discussing the behavior description approach (a consociative approach) to task classification, Hackman (1968) states:

> "While the task as behavior description approach may be useful in grouping and identifying behavior emitted by people working on tasks or jobs, it probably will not prove useful in understanding how tasks effect behavior. It appears that some researchers concerned with job and task descriptions have, in effect, substituted a dependent variable class for what should be an independent variable class. That is, if we are interested in the effects of tasks and task characteristics on behavior, it is essential that we develop means of describing and classifying our independent variables (tasks) other than in terms of the dependent variables (behavior) to which we ultimately wish to predict."

The confusion which exists in psychology as to the value and possible functions of consociative classifications is a result of psychologists' failure to recognize the limited applicability and theoretical value of classifications which describe tasks in terms of exoteric variables of interest. In general, psychology has ignored the theoretical approach to task classification in favor of the consociative approach probably because of the inherent difficulty in developing task qua task descriptors for the theoretical approach. However, since psychology has not developed a theoretical classification of tasks, it should not delude itself by attributing some of the value and properties of the theoretical approach to the consociative approach.

WHAT DO BIOLOGISTS CLASSIFY?

The question of what the biologists classify is not quite as simple as it first appears. The obvious answer to the question is that biologists classify living organisms. But this is not always the case, although living organisms are always involved. What is to be classified is dependent upon and can only be determined by the "why" of classification. If the purpose of a biological classification is ecological, then the relationships of organisms to environmental factors are classified. If the purpose is teleological, then the uses of organisms to man are classified. And, if the purpose is theoretical, organisms are classified. Thus, only in theoretical classification is the obvious answer the correct answer; only in theoretical classification does the resulting sets or classes represent organisms as organisms. This fact emphasizes the priority of the "why" of classification over the "what" of classification. Only when the purpose of the classification has been established can the subject matter of the classificatory system be determined.

This situation extends to the domain of task classification. In psychology what have been referred to as task classifications are not "classifications of task". The major reason for this is that the subject matter which constitutes the bases for these classifications is not the tasks themselves, but rather it is the relationship of tasks with either what the operators actually do on a task or what is required of them on a task. When the relationships of tasks to exoteric variables is considered, the purpose of the classification is consociative. Tasks become the subject matter of classification only when the purpose of the classification is theoretical and tasks *qua* tasks are considered.

HOW DO BIOLOGISTS CLASSIFY?

Ecological and Telecological Classification

As far as the present author can determine there has been no explicit taxonomy developed in biology for the "how" of ecological and teleological classification. For the most part ecological and teleological classifications are *ad hoc* efforts and, hence, little effort has been invested in the development of a taxonomy for these types of classification. The lack of a taxonomy for ecological and teleological classification seems to be largely due to the fact that the biologists posit no general usefulness or theoretical value for either ecological or teleological classification.

Theoretical Classification

Modern taxonomic thought in biology appears to be dominated by three schools of thought which, in the present paper, will be referred to as Linnaean taxonomy, Darwinian taxonomy and Numerical taxonomy.[12] Of these three, Linnaean taxonomy is historically the oldest; Darwinian taxonomy is the most popular; and Numerical taxonomy

---

12

Although theoretical classification will be divided into these schools of thought, there are probably more similarities than differences among them. The tripartite division was made primarily to facilitate the discussion of certain key taxonomic differences. It is not being suggested that any modern taxonomist is practicing taxonomy in the same fashion that of Linnaeus, Darwin or Adanson. Rather, it is suggested certain underlying assumptions, introduced by these early thinkers, have been preserved in modern taxonomic thought and that these assumptions comprise the essential differences between the "schools of thought".

is a modern variation of an old concept. To be sure, there are taxonomic biologists who would not permit themselves to be classified under one of these three headings. However, most taxonomic thought in biology seems to be adequately represented by these categories. Therefore, the following discussion of how theoretical classifications are developed in biology will center about these schools of thought. Before commencing the discussion, it should be noted that each of the above schools of thought probably would accept the definition of classification given on page iv of this report. The definition is explicity accepted by the Darwinian taxonomists (Simpson, 1961, p. 11)[13] and by the Numerical taxonomists (Sokal & Sneath, 1963, p. 3). The writings of the Linnaean taxonomists suggest that it would also be acceptable to them. Given this agreement on the definition of classification, the debate among the three schools of thought over how a theoretical classification should be developed reduces to an argument concerning how to develop the associations by contiguity and similarity specified in the definition of classification.

Linnaean taxonomy. Modern systematic biology began in the first half of the 18th century with the classificatory efforts of Linnaeus. During this period the prevailing logic of science was scholastic or Aristotelian logic and, because of this, Linnaean taxonomy is based upon this system of logic. The use of Aristotelian logic reduces the "how" of classification to an attempt to define the essence or essential nature of a group of organisms. This is made explicit by Blackwelder and Boyden (1952) who state that "The grand object of classification everywhere is

---

13

It should be remembered that Simpson modifies the definition somewhat in considering evolutionary origin and phylogenetic relationships as valid classificatory associations.

the same. It is to group the objects of study in accordance with their essential natures" (p. 34). In addition to defining the essence of an organism, the Linnaean systematist, in order to classify that organism, must be able to distinguish among the organism's species, genus, differentiae, properties and accidents. Simpson (1961) provides the scholastic definitions of these five terms.

> Species: "a group of things similar in essence" (p. 24).
> Genus: "that part of the essence shared by distinct species, hence by extension... a group of species... with some attributes in common" (p. 24).
> "Differentia: that part of the essence peculiar to a given species and therefore distinguishing it from other species.
> Property: an attribute shared by all members of a species but not part of its essence and not necessary to differentiate it.
> Accident: an attribute present in some members of a species but not shared by all and not part of its essence" (p. 24).

Any attempt to define the essence of an organism and, in so doing, to discriminate among the above five elements, involves a large amount of a priori, subjective judgment. The subjectivity arises from the fact that the systematist must critically examine the organism and extract only those features of the organism which, in his opinion, comprise its essential nature. Such subjectivity can never serve as the basis of a scientific classification, mainly because of its inherent lack of testability. The use of subjectivity in classification prompted Michener and Sokal (1957) to write: "Taxonomy, more than most other sciences, is affected by subjective opinions of its practitioners. Except for the judgment of his colleagues there is virtually no defense against the poor taxonomist" (p. 159).

Considered in another sense, the process of defining the essence of the objects to be classified is highly similar to the process of assigning a priori weights to the unit characters upon which objects are

to be compared and classified. In defining the essence of an object, the systematist gives unit weights to those features of the object which comprise its essence and gives a weight of zero to all of the remaining features of the object. There can be little justification for such procedures.

Linnaean taxonomy is vulnerable to still another criticism because of its use of Aristotelian logic. This criticism is given by Sokal and Sneath (1963) with reference to the early Linnaean taxonomists. However it still is valid with respect to their modern counterparts.

> 'The Aristotelian system as applied to taxonomy consisted in the attempt to discover and define the essence of a taxonomic group (what we may somewhat loosely think of as its "real nature" or "what makes the thing what it is"). In logic this essence gives rise to properties which are inevitable consequences: for example, the essence of a triangle on a plane surface is expressed by its definition as a figure bounded by three straight sides, and an inevitable consequence is that any two sides are together longer than the third. Such logical systems are known as systems of analyzed entities, and early systematists supposed that biological classifications could be of this kind.....Aristotelian logic does not, however, lend itself to biological taxonomy, which is a system of unanalyzed entities, whose properties cannot be inferred from the definitions' (p. 12).

Lastly, Linnaean taxonomists encounter another difficulty in attempting to create taxa through the definition of essences. In some instances when essences are used to define a group, the resulting group is monothetic.[14] "The ruling idea of monothetic groups is that they are formed by rigid and successive logical divisions so that possession of a unique set of features is both sufficient and necessary for membership in the group thus defined" (Sokal & Sneath, 1963, p. 13).

---

[14] In a monothetic group each member possess all of a unique but limited set of features. In many instances the features must be possessed to the same degree.

The greatest danger in the use of monothetic groups is that an organism, which is aberrant in but one of the features employed to make the primary division for a given group, will inevitably be classified in a category far removed from that group.

Even though psychology has yet to produce a true theoretical classification of tasks, most of the criticism which has been voiced against Linnaean taxonomy can be validly applied to psychology's efforts in consociative classifications. Many consociative classifications of tasks are quite similar to Linnaean classifications of ogranisms. This is probably best seen in an example. When a psychological systematist defines a group of tasks as "tracking" tasks, he has in all reality defined the essence of those tasks. In another sense, he has given an a priori weight of one to those features (whether specified or unspecified) which in his opinion constitute "tracking". He has also implicitly given a weight of zero to all of the other features of the tasks. Lastly, he has rejected any notion of the overall similarity of the tasks and instead, has created a monothetic group.

Although much Linnaean thought is evident in this type of task classification, psychologists have not carried this type of classification as far as the Linnaean biologists have. For example, psychologists have not developed explicit concepts of genera of tasks existing above the task species level.

With respect to the task taxonomy, the Linnaean approach to classification appears to be of little value because of its extreme vulnerability to criticism. This vulnerability is now being recognized by the biologists and as a consequence Linnaean taxonomy is becoming less popular in biology.

Darwinian taxonomy. The impact of Charles Darwin's theory on biology cannot be underestimated. The concepts of evolution which

he introduced in 1859 revolutionized biology and to this day still permeate biological thought. For many modern biologists his theory of evolution constitutes the only valid taxonomic basis for the classification of organisms. This fact is evident in the writings of Simpson. Simpson (1961) states "Species exist because they evolved. That, in briefest form, is the natural reason for the existence of species and is therefore also the truly natural basis for classification" (p. 57). Stated in other terms, the Darwinian taxonomists hold that a classificatory group can only be established on the basis of common evolutionary descent or on the basis of homologous characters.[15] The use of evolutionary theory as a basis for classification is fraught with difficulties and as a result, has been rejected both by the Linnaean taxonomists and by the Numerical taxonomists.

In rejecting evolutionary taxonomy, Borgmeier (1956, p. 54-55) makes the following statement:

> 'Systematics is independent of the theory of descent. This is admitted today even by convinced evolutionists. The reasons are as follows. (1) Systematic methods provide definite results without reference to the idea of evolution; phylogenetics has no special methods, it is essentially the interpretation of systematic facts. (2) Systematics is a science; phylogeny is a hypothesis of a historical process containing a fundamentally unverifiable element and can therefore never be the foundation of a science. (3) Systematics is the investigation of facts; phylogenetics is often "a dangerous play with mere possibilities" (Hennig); Kant called it "a daring adventure of the mind."'

15

Homologous characters are a complex of characters having a common ancestral origin.

The use of phylogeny as the taxonomic basis for classification is similarly rejected by Sokal and Sneath (1963, p. 56-57).

> "Not only do we insist on the separation of phenetic[16] from phyletic[17] considerations in taxonomic procedure, but we also feel that only phenetic evidence can be used to establish a satisfactory classification. We hold this belief for two reasons.
>
> (1) The available fossil record is so fragmentary that the phylogeny of the vast majority of taxa is unknown....
>
> (2) Even when fossil evidence is available, this evidence must first be interpreted in a strictly phenetic manner... since the criteria for choosing the ancestral forms in a phylogeny are phenetic criteria and are based upon phenetic relationships between putative ancestor and descendant."

In addition to the above criticisms of Darwinian taxonomy, fault has also been found with the use of homologous characters for the establishment of taxa. Sokal and Sneath (1963) present two arguments against the use of homology.

> "In determining which characters are homologous (of common descent) and which have been independently evolved, the systematist has to express a judgment on the relative probability of the independent origin of different character complexes" (p. 22).
>
> "Classifications are only as good as the homologies of the characters on which they are based. Furthermore, decisions on homologies of certain characters are based upon the validity of the classification of the groups involved in the argument; this classification in turn is based upon homologies of other characters used to establish the classification ab initio. When the circular arguments are interrupted we are left with much uncertainty" (p. 23).

16 Phenetic or static relationships are relationships or "resemblances existing now in the material at hand" (Sokal & Sneath, 1963, p. 55).

17 Phyletic relationships are relationships on the basis of a hypothesized evolutionary descent.

Homology has also been subjected to the same criticisms which have been employed against the Linnaean concept of essence. These criticisms are valid with respect to homology since in many instances the homologous characters which are used to establish taxa are no more than phylogenetic essences. A discussion of these criticisms can be found in the preceding section of this report which treats on Linnaean taxonomy.

In responding to the above criticisms, the Darwinian systematists attempt to define their problems out of existence by referring to taxonomy as both a science and an art. "Its scientific side is concerned with reaching approximations,..., toward understanding of relationships present in nature.... and taxonomy becomes largely aristic,..., when applied to the construction of classifications." (Simpson, 1961, p. 110). The weakness in this concept can be most easily seen in the principles of "taxonomic art" offered by Simpson (1961, p. 110-111).

> "A basic principle of taxonomic art is that its results should be useful. In classification, this entails, among other things, three especially important subsidiary principles:
> 1. The basis of classification should be the most biologically significant relationships among organisms and should bring in as many of those as is practicable.
> 2. Classification should be consistent with the relationships used in its basis.
> 3. Classification should be as stable as it can be without contravening the two preceding principles."

No quarrel can be had with the statement that the results of taxonomy "should be useful". However, it should be noted that the use of deductive theory and of opinions as to which characteristics of an organism are essential or homologous is not the only means of

constructing a useful classification. The three subsidiary priniciples all fall victim to the subjectivity inherent in the concept of taxonomy as art. How does one recognize "the most biologically significant relationships among organisms"? Are not the relationships employed as the basis for classification hypothesized relationships derived from a deductive theory? How can one expect agreement among systematists, and hence stability in classification, when the touchstone for classification is the opinion of its practitioner?

For the most part, the criticisms which have been directed at Darwinian taxonomy have been quite valid. These criticisms point out an essential and basically insurmountable difficulty in the Darwinian approach which should be noted with respect to task taxonomy. The difficulty in the Darwinian approach is that it attempts to base a scientific classification on a theory which is deductive or at best vaguely inductive. The issue here is not a simple quibble as to the merits of deductive theory. To be sure, deductive theory has its place in science. Deduction cannot be ruled out as a valuable method for achieving knowledge. As applied to classification deductive theory can be employed to explain relationships found in classifications and to guide the taxonomist in his search for new classificatory relationships. However, deductive theoretical speculations can be ruled out as a basis for scientific classification since they do not provide the necessary type of relationships. In order to constitute a stable, generally useful tool a scientific classification must be founded upon relationships which are factual, that is, the relationships must have been derived directly from data (See Appendix, steps 4 and 5). A scientific classification cannot be founded upon hypothesized relationships or speculations which merely reflect the subjective opinions of some systematist.

Numerical taxonomy. The origins of Numerical taxonomy can be traced to the 1700's and the taxonomic efforts of Adanson, who is generally cited as a founder of empiricism in biological taxonomy and

classification. Adanson's major contributions to biological taxonomy were that "he rejected the a priori assumptions on the importance of different characters (which were a consequence of Aristotelian logic)" and that 'he correctly realized that natural taxa are based on the concept of "affinity" -- which is measured by taking all characters into consideration -- and that taxa are separated from each other by means of correlated features' (Sokal & Sneath, 1963, p. 16). In Adanson's day, these were major insights which were revolutionary with respect to the then prevalent Linnaean thought. However, the development of these concepts was retarded until the early 1950's primarily because of the impact of evolutionary theory on the science of biology and also because of the lack of the computational capacity necessary to process large amounts of data prior to 1950. The modern continuation of Adansonian thought is Numerical taxonomy which has been defined by Sokal and Sneath (1963, p. 48) as "the numerical evaluation of the affinity or similarity between taxonomic units and the ordering of these units into taxa on the basis of their affinities."

As has been shown in two previous sections of this report, the major objection which the Numerical taxonomists have against Darwinian and Linnaean taxonomy is the large amount of subjectivity inherent in the classifications which are products of these two schools of thought. In order to eliminate the subjectivity inherent in assumptions concerning "essence" or "phylogeny" and to render classification a scientific effort, the Numerical taxonomists established repeatability and objectivity as the outstanding aims of their approach.

> "Although we cannot expect scientists always to agree on interpretations of facts, it is the aim of scientific methodology to reach agreement on the facts themselves through the repeatability of observations. It is in this direction that numerical taxonomy aims. We hope by numerical methods to approach the goal where different scientists working independently will obtain accurate and identical estimates of the

resemblance between two forms of organisms, given the same characters on which to base their judgment. Classification must be freed from the inevitable individual biases of the conventional practitioner of taxonomy.

Closely tied up with repeatability is the notion of objectivity.... By including many characters without previous arbitrary selection or elimination, and by providing standard methods of processing the data[18] and evaluating the results, we reduce subjective bias and hence increase objectivity" (Sokal & Sneath, 1963, p. 49-50).

In essence, these concepts of repeatability and objectivity are the only things which separate the Numerical taxonomists from the Darwinian and Linnaean taxonomists. While the Darwinian and Linnaean taxonomists would permit opinion to enter into the foundations of classification, the Numerical taxonomists feel that classifications must be established on stable, objectively derived, data bases. They insist that hypothesized relationships do not provide an adequate basis for scientific classification. With particular respect to the Darwinian taxonomists, the Numerical taxonomists ask that the implicit, subjective organizations of observations, which give rise to deductive theory, be formalized in explicit classifications and that these classifications be founded upon empirically established relationships in the data. A very interesting comment has been made on this point by Simpson, a Darwinian who rejects Numerical taxonomy and who asserts that the theory of evolution is the only valid basis for classification. Simpson (1961, p. 41) states that "Adanson's approach was, ..., the one best suited to provide the evidence and basis for evaluations and criteria that were later to be supplied by evolutionary theory.... Adanson and his followers built a generally sound foundation."

---

18 The exact statistical and numerical procedures which the biologists employ will not be discussed in this paper. For the most part the biologists look to psychometrics for their procedures referencing authors such as C. R. Rao, R. D. Bock, H. H. Harman and S. S. Wilks.

In developing their taxonomy so as to fulfill the aims of repeatability and objectivity, the Numberical taxonomists offer the following axioms:

> "(1) The ideal taxonomy is that in which the taxa have the greatest content of information and which is based on as many characters as possible.
>
> (2) A priori, every character is of equal weight in creating natural taxa.
>
> (3) Overall similarity (or affinity) between any two entities is a function of the similarity of the many characters in which they are being compared.
>
> (4) Distinct taxa can be constructed because of diverse character correlations in the groups under study.
>
> (5) Taxonomy as conceived by us is therefore a strictly empirical science.
>
> (6) Affinity is estimated independently of phylogenetic considerations" (Sokal & Sneath, 1963, p. 50).

The first of the above axioms is an effort by the Numerical taxonomists to meet Gilmour's dictum that "The primary function of classification is to construct classes about which we can make inductive generalizations" (1951, p. 401). The acceptance of this dictum by Sneath is made clear in his statement that "the function of scientific classification is to enable us to make predictions about unknown and unexplained properties" (1957b, p. 196). In order to follow this principle and to maximize the range of possible inductive generalizations, the Numerical taxonomists require that a classification must have a high information content; "the raison d'etre of a scientific classification is its high information content (its predictive value)" (Sneath, 1957b, p. 196).

The second axiom is a protection against any bias or preselection in the choice of characters for study. The Numerical taxonomists insist that the concepts of a priori weighting, essence, and homologous characters be eliminated from taxonomic and systematic practice.

The third axiom is an expression of the Numerical taxonomists' opinion that similarity can be established only by comparing organisms on all of the characters that possibly can be obtained. The range of characters which the Numerical taxonomists consider in classifying organisms includes:

> "(a) morphological characters (external, internal, microscopic, including cytological and developmental characters),
>
> (b) physiological characters
>
> (c) behavioral characters
>
> (d) ecological and distributional characters (habitats, food, hosts, parasites, population dynamics, geographical distribution)" (Sokal &Sneath, 1963, p. 93).

When such a diverse array of characters is considered, the work load involved in establishing taxa quickly becomes enormous. This is one reason the development of Numerical taxonomy was delayed until the advent of electronic computers. An example of the amount of work involved in the Numerical approach is a study by Michener and Sokal (1957) in which the authors considered 11, 834 characters in dividing the Hoplitis complex of bees into 97 species. Although the consideration of many characters makes the classification of even the most limited set of organisms a large undertaking, Sneath (1957b), argues that it is better to examine a few organisms on many characters than to examine many organisms on a few characters since "it is better to have two firmly established species than to find (by using many strains[19]) four or five poorly established species. There are enough of the latter already cluttering the literature" (p. 193).

---

19 Refers to strains of bacteria.

The fourth axiom is merely a statement that taxa should be established by numerical methods. The methods suggested by the Numerical taxonomists include cluster analysis (broadly considered), factor analysis, and multisimensional scaling.

A corollary to these first four axioms is that the taxa which result from their application must be polythetic[20] rather than monothetic as in Darwinian and Linnaean classifications.

The fifth axiom is the result of the first four axioms in that the preceeding axioms eliminate subjectivity from classification and base classification on empirical observations and data.

Lastly, the sixth axiom is a statement of the position of the Numerical taxonomists that, while evolutionary (deductive) theory provides a valid explanation for classificatory arrangements, it does not provide an adequate basis for classification. This statement should not be interpreted as being anti-theoretical. "As it happens, all the proponents of numerical taxonomy are evolutionary biologists in their own right.... They are criticizing not evolution or the study of phylogeny but speculation passed off as fact" (Sokal & Sneath, 1963, p. 56).

As far as the present author can determine there have been no major criticisms of Numerical taxonomy. The only criticism which has been voiced against the Numerical taxonomists is a very poor one offered by Simpson (1961, p. 41):

> "The very fact that it (Numerical taxonomy)[21] was to a great extent nontheoretical meant that it lacked an explanatory element, a meaningfulness, a judgement that can only be provided by

---

20 "A polythetic arrangement..., places together organisms that have the greatest number of shared features, and no single feature is either essential to group membership or is sufficient to make any organism a member of a group" (Sokal & Sneath, 1963, p. 14).

21 The phrase in the parentheses was added by the present author.

> some form of theoretical evaluation of the data... One cannot say of modern Adansonians... that they are wrong, but only that their work is shallow and incomplete."

Such a criticism reflects a complete misreading of the position of the Numerical taxonomists. In no sense are the Numerical taxonomists nontheoretical. They simply insist that deductive theory, hypothesized relationships, and speculation have no place in the foundation of classifications. Their positicn can be seen in the quote from Sokal and Sneath given above.

SUMMARY AND CONCLUSIONS

Although it has not provided specific solutions to the problems of the taxonomy and classification of tasks, the present review of biological taxonomy and classification has provided some theoretical considerations which should be of value to systematic psychologists in approaching the problems involved in the organization of current knowledge relating to tasks and task performance. In addition, the review has indicated some of the conceptual difficulties which systematic biologists have encountered, and therefore, which should be avoided by psychology.

One of the more important points which has been noted is that a taxonomy is a prerequisite for classification. That is, the organization of tasks, or of any subject matter, into groups requires the previous development of a sound logic and rationale for the organization. Without a well-developed taxonomy classification is generally a futile effort. The presence of logical errors in the taxonomic foundations of a classification almost certainly destines classification to failure. Throughout their history, systematic psychologists have not invested any effort in developing a taxonomy prior to classifying. For the most part, they have been all too ready to classify. "It may be that taxonomists are too overwhelmed with the sheer bulk of the material confronting them that still requires description and classification to have time to work on a theory of taxonomy. However, we hardly feel that this is a case where *tout comprendre, c'est tout pardonner*" (Sokal & Sneath, 1963, p. 10). Taxonomy is too critical to classification to be ignored.

In developing the rationale for a classification the following questions must be considered: (1) Why do you want to classify, (2) What will you classify and, (3) How will you classify? Not only is it

essential to consider these questions but they must be considered in the order in which they are presented above. The answers to the second and third questions depend upon the answer to the first question. Decisions on what is to be classified and on how it is to be classified cannot be reached until one knows why the classification is being developed. In other words, the subject matter of the classification and the related classificatory procedures are dependent upon the purpose of the classification. Initially, this can appear to be an obvious, even trivial point until one notices that it is quite abused and disregarded in psychology. Historically, psychology's attempts to classify tasks have classified the relationships of tasks to sets of exoteric variables rather than classifying the tasks themsleves. If the purpose of classification is to reveal the interrelationships among tasks as tasks, then the proper subject matter for the classification is the characteristics and properties of the tasks themsleves.

The consideration of the purpose of classification leads to the definition of three types of classifications each with its particular attributes, uses and limitations. Although it appears to be of little scientific interest to psychology, a teleological classification of tasks can be developed in order to group tasks on the basis of their usefulness with respect to man. An example of this type of classification is R. B. Miller's classification of tasks into "nonsense tasks" and "real world tasks".

Consociative classifications of tasks can be developed if the purpose of the classification is to relate tasks to variables of interest which are not inherent attributes or characteristics of the tasks themselves, such as inferred processes in the operator or principles of learning. Consociative classifications of tasks are not generally applicable and do not possess a high content of information concerning the tasks themselves. Although they are valuable scientific tools, it

should be noted that the generality and pragmatic value of consociative classifications are limited to the scope and degree of applicability of the exoteric variables which constitute the subject matter of these classifications. For example, a classification of tasks in terms of learning principles might be of great value in developing training methods but would not provide any real guidance in the areas of personnel selection or systems design. By far the overwhelming majority of classifications of tasks which have been developed to date are consociative classifications.

The third type of classification, <u>theoretical</u> classification, describes tasks in terms of the inherent attributes and characteristics of the tasks. Since they are the only classificatory vehicles which possess a high content of information concerning the tasks as tasks, they are the only classifications of tasks which can relate essential information concerning the tasks themselves to sets of exoteric variables. Psychology has yet to develop a theoretical classification of tasks, although Hackman (1968) has suggested a task <u>qua</u> task approach to classification.

Under the heading of theoretical classification the present review discussed three "major schools of thought" in biology concerning how to develop the classification systems. The first of these schools of thought, Linnaean taxonomy, suggests that the basis of the classification be formulated around the scholastic concept of "essence". The major flaw in this approach lies in the fact that <u>a priori</u> subjective judgments are required to define the "essential nature" of the objects or events to be classified. Considered in another sense, the process of defining the essence of an object amounts to assigning <u>a priori</u> weights of one to certain characteristics of the object and of zero to other characteristics. This philosophy of classification normally produces monothetic systems wherein possession of a unique set of features is both necessary and sufficient for membership in a group. Thus, an object which is

abberant in but one of these features can possibly be classified in a category far removed from that group.

As was mentioned in an earlier section of this report, almost all of the task classifications, which have been thus far developed in psychology, have been essentially Linnaean classifications. For the most part, the existing task classifications have been developed by means of a critical examination of a set of tasks followed by the creation of a word or phrase which supposedly describes the essence or essential nature of that group of tasks. Since most task classifications are of this type, there is quite some support in psychology for the Linnaean approach. Many psychologists would argue that the Linnaean classification of fauna was a useful tool for its time since it organized observation and reporting even though it was as preliminary as Thorndike's Law of Effect. True the Linnaean system organized information, but this does not in itself justify its use in classification. Nor can its use be endorsed on the basis of the embryonic state of biology in the 1700's. As primitive as the science of biology was in the 1700's, Adanson's empirical efforts not only supplied organization to biological information but also his classification systems have proved to be more stable than the comparable Linnaean systems.

Thus, it should not be suggested that the rudimentary state of systematic psychology permits psychologists to employ the most archaic and rudimentary methods in developing task classifications. Two hundred and fifty years of experience in biology have revealed that the Linnaean approach is completely inadequate for classification. As a result of this realization, Linnaean taxonomy has decreased in popularity over the last 100 years to the point where, today, it seems to be completely disappearing. It has become blatantly obvious to most biologists that the scholastic concept of essence is not amenable with scientific classification.

The second approach to biological classification discussed in the review is the Darwinian approach. This approach is characterized by the use of a deductive theory concerning the phylogenetic origins organisms as the basis for the establishment of a classification. The major criticism concerning this use of a deductive theory as the basis for a classification is that, since the theory contains a fundamentally unverifiable unit, the interpretation of the facts should be independent of systematic practice. In addition, the Darwinian approach is vulnerable to the criticisms put forth against the Linnaean approach since the use of groups of characters with a hypothesized common descent is no more than the use of a concept of phylogenetic "essence".

In general, the Darwinian approach to classification does not appear to have anything to offer with respect to the classification of tasks. The major reason for this is that (as far as the present author can determine) psychology does not possess a theory of tasks upon which a classification of tasks can be established. Even if such a theory were available, the advisability of its use as a basis for classification would be highly questionable. Classifications must be founded upon facts. Theories cannot be substituted for facts since theories are speculations on the nature of facts. If deductive theory is permitted as a basis for classification, there could be as many classifications as there are theorists and the resulting classifications will only be as stable as the speculations upon which they are founded.

Of the three major biological taxonomic approaches to classification, only Numerical taxonomy seems to present a philosophy of classification which would be useful for task classification. In an effort to avoid the difficulties inherent in those approaches which permit opinion and speculation to enter into the bases of classification, Numerical taxonomy strives for repeatibility and objectivity in classification. The aim of this effort is to provide a body of facts upon which all researchers would agree. In addition, the elimination of arbitrary preselection of the unit characters upon which the classification is to be

based increases the information content of the classification and the range of possible inductive generalizations. One result of this approach to classification is that the classes are polythetic. That is, membership in a given class is based solely upon overall similarity and it is not possible to specify a unique set of characters which are both necessary and sufficient for group membership. On these bases classification is viewed as a strictly scientific effort and all concepts of classification as an art are discarded.

One final insight into the problems of taxonomy and classification can be obtained from the present review of biological systematics. When viewed in light of biology's experience, the inability of psychologists to develop, over the last 75 years, reliable and valid classifications is neither surprising nor disheartening. Progress in the science of systematics is the result of a slow and tedious process.

In the 250 years since Linnaeus, biology has not been able to produce any ready solutions for the problems in taxonomy and classification. To the naive observer this might seem incomprehensible since the grand classificatory schemes which exist in biology superficially appear to promise much for task classification. However, this is not the case. Much of the biologists apparent progress in classification is due to a fortunate quirk in their subject matter, rather than to superior taxonomic or classificatory practice. "The majority of (biological)[22] taxa are definable because of the discontinuities arising in phyletic lines as by-products of the evolutionary process" (Sokal & Sneath, 1963, p. 10). Years of experience with these obvious discontinuities (fish vs. mammals, eagles vs. robins) have allowed the biologists to easily devise classifications. However, in those instances (and they are many) where the discontinuities are not so obvious, stable classifications have not been produced. One could easily hazard a guess that the situation in biology would not be vastly different from that in psychology, if one were as free to create organisms to fill the gaps in nature as one is free to device tasks to fill the gaps between apparent groups of tasks.

---

[22] The phrase in parentheses was added by the present author.

REFERENCES

Blackwelder, R. E., & Boyden, A. The nature of systematics. Syst. Zool., 1952, 1, 26-33.

Borgmeier, T. Basic question of systematics. Syst. Zool., 1956, 5, 53-69.

Gilmour, J. S. L. A taxonomic problem. Nature, 1937, 139, 1040-1042.

Gilmour, J. S. L. Taxonomy and philosophy. In J. S. Huxley (Ed.), The New Systematics. Clarendon Press: Oxford, 1940, 461-474.

Gilmour, J. S. L. The development of taxonomic theory since 1851. Nature, 1951, 168, 400-402.

Hackman, J. R. Tasks and task performance in research on stress. In J. E. McGrack (Ed.), Social and psychological factors in stress. New York: Holt, Rhinehart & Winston, 1968.

Michner, C. D., & Sokal, R. R. A quantitative approach to a problem in classification. Evolution, 1957, 11, 130-162.

Simpson, G. G. Principles of Animal Taxonomy. Columbia University Press: New York, 1961.

Sneath, P. H. A. The application of computers to taxonomy. J. Gen. Microbiol., 1957, 17, 201-226.

Sneath, P. H. A. Some thoughts on bacterial classification. J. Gen. Microbiol., 1957, 17, 184-200. (b)

Sokal, R. R. & Sneath, P. H. A. Principles of Numerical Taxonomy. W. H. Freeman and Co.: San Francisco, 1963.

Wheaton, G. R. Development of a Taxonomy of Human Performance: A Review of Classificatory Systems Relating to Tasks and Performance. Washington, D. C.: American Institutes for Research, 1968. AIR-726-12/68-TR-1.

APPENDIX

OUTLINE OF THE SCIENTIFIC METHOD

Iterative Process

1. Identify Problem
   - State in empirical terms (relationships among variables)
   - Relate to a theory if one exists in a usable form

2. Define an Observable Phenomenon

3. Obtain Data
   - Must be reproducible under well-defined, specified conditions
   - Must have common or translatable measurement so it can be related to other work in the area

4. Obtain Relationships from the Data

5. Classify
   - Organize the data on the basis of the relationships

6. Theorize
   - Explain the relationships in the organized data

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) American Institutes for Research 135 North Bellefield Avenue Pittsburgh, Pennsylvania 15213	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

DEVELOPMENT OF A TAXONOMY OF HUMAN PERFORMANCE: A REVIEW OF BIOLOGICAL TAXONOMY AND CLASSIFICATION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Scientific Interim

5. AUTHOR(S) (Last name, first name, initial)

George C. Theologus

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO OF REFS
December 1969	41	12

8a. CONTRACT OR GRANT NO. F44620-67-C-0116(ARPA)	9a. ORIGINATOR'S REPORT NUMBER(S) AIR-726-12/69-TR-3 R70-4
b. PROJECT NO. 9743	
c. 61101D	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFOSR-70-0929TR
d. 681313	

10. AVAILABILITY/LIMITATION NOTICES

1. This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES TECH, OTHER	12. SPONSORING MILITARY ACTIVITY Air Force Office of Scientific Research 1400 Wilson Boulevard (SRLB) Arlington, Virginia 22209

13. ABSTRACT

This review of systematic biology was undertaken to determine whether any of the concepts and methods from systematic biology could be applied to the problems of task taxonomy and task classification. Although the review found that biology could not supply ready solutions to problems in the classification of tasks, certain taxonomic concepts were extracted which should be of value. The importance of a well-developed logic and rationale for classification was noted. Moreover, it was determined that the purpose of a classification must be established before the nature of the objects to be classified or the methods of classification can be specified. In considering the logic for classification three types of classification were identified and defined: teleological, consociative, and theoretical classification. Of these three, only theoretical classifications, classifications which describe the objects of interest in terms of inherent attributes of the objects themselves, are generally applicable or theoretically useful. Three approaches to the development of theoretical classification also were considered. Linnaean taxonomy which employes scholastic logic to develop classifications and Darwinian taxonomy which employes a deductive theory were rejected for use in task classification on the basis of their vulnerability to criticism. Numerical taxonomy, the most empirical of the three biological approaches to classification, was found to provide a sound

(Continued)

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

13. Abstract (Continued) AFOSR-70-0929TR

basis for the development of classificatory systems and was suggested as a model for the development of task classifications.